# CLAIMS

1. A device comprising an electrochemical fuel cell, said fuel cell comprising:

a membrane electrode assembly interposed between an anode flow field and a cathode flow field of said fuel cell;

a first reactant supply and a cathode flow field exhaust in communication with said cathode flow field;

a second reactant supply and an anode flow field vent valve in communication with said anode flow field;

at least one condition monitor configured to generate a signal indicative of a condition of a component of said fuel cell; and

a vent valve controller programmed to control an operating state of said vent valve as a function of said condition signal and a calculated dilution gas crossover rate of said membrane electrode assembly.

2. A device as claimed in claim 1 wherein:

a dilution gas concentration in said anode flow field is determined as a function of a calculated dilution gas crossover rate of said membrane electrode assembly; and

said vent valve is opened when said dilution gas concentration in said anode flow field is above a high threshold value and closed when said dilution gas concentration in said anode flow field is below a low threshold value.

3. A device as claimed in claim 1 wherein said dilution gas crossover rate of said fuel cell is calculated as a function of fuel cell temperature and an estimate of nitrogen partial pressure across said membrane electrode assembly.

4. A device as claimed in claim 3 wherein said estimate of nitrogen partial pressure across said membrane electrode assembly is determined from $N_C$ and $N_A$, where $N_C$ represents nitrogen partial pressure in said cathode flow field and $N_A$ represents nitrogen partial pressure in said anode flow field.

5. A device as claimed in claim 4 wherein $N_C$ is determined from the molar fraction of nitrogen in said first reactant supply and cathode flow field temperature, pressure, and $H_2O$ vaporization pressure.

6. A device as claimed in claim 5 wherein said cathode flow field temperature and pressure are taken as an average of a measurement at an inlet of said cathode flow field and an outlet of said cathode flow field. Is this too specific?

7. A device as claimed in claim 3 wherein $N_A$ is determined from the molar fraction of nitrogen in said anode flow field $mf_{N_2}$ and anode flow field pressure $P_{tot}$.

8. A device as claimed in claim 7 wherein said molar fraction of nitrogen in said anode flow field $n_{N_2}$ is determined according to the following equation

$$mf_{N_2} = \frac{n_{N_2}}{n_{anode}}$$

$$n_{H_2O} + n_{H_2} + n_{N_2} = n_{anode}$$

where $n_{H_2O}, n_{H_2}, n_{N_2}$ represent respective amounts of water vapor, hydrogen, and nitrogen in said anode flow field.

9. A device as claimed in claim 8 wherein the amount of water vapor in said anode flow field is determined according to the following equation:

$$n_{H_2O} = \frac{RH * P_{vap} * n_{anode}}{P_{tot}}$$

where $RH$ represents the relative humidity in the anode, $P_{vap}$ represents the vapor pressure of water in the anode, and $P_{tot}$ represents ~~total~~ anode pressure.

10. A device as claimed in claim 1 wherein said dilution gas crossover rate of said fuel cell is calculated utilizing the following equation:

$$V_{N_2} = 10^{-10} \frac{P_{N_2} A \Delta p_{N_2}}{t}$$

where $V_i$ represents volumetric flow across the membrane of said membrane electrode assembly, $P_i$ represents a permeation coefficient of said membrane, $A$ represents membrane surface area, $\Delta p_i$ represents the partial pressure differential of said dilution gas across said membrane, and $t$ represents membrane thickness.

11. A device as claimed in claim 10 wherein said permeation coefficient of said membrane is determined as a function of fuel cell temperature.

12. A device as claimed in claim 11 wherein said dilution gas comprises nitrogen, said membrane electrode assembly comprises NAFION, and said permeation coefficient $P_i$ of said membrane is determined according to the following equation:

$$P_{N_2} = 3.07 * 10^4 e^{-2160/T}$$

wherein T represents fuel cell temperature.

13. A device as claimed in claim 1 wherein said dilution gas crossover rate of said fuel cell is calculated from data representing:

$P_i$, a permeation coefficient of said membrane;

$A$, membrane surface area;

$\Delta p_i$, partial pressure differential of said dilution gas across said membrane; and

$t$ membrane thickness.

14. A device as claimed in claim 1 wherein said vent valve controller is programmed to integrate said crossover rate to yield a molar fraction calculation of said dilution gas in said anode flow field.

15. A device as claimed in claim 1 wherein said vent valve controller is programmed to calculate an aggregate dilution gas concentration in said anode flow field.

16. A device as claimed in claim 15 wherein an indication of an amount of gas vented through said anode flow field vent valve is used to calculate said aggregate dilution gas concentration.

17. A device as claimed in claim 1 wherein said vent valve controller is programmed to control an operating state of said vent valve independent of an operating output voltage of said fuel cell, output voltage statistics, cell voltage decay, and combinations thereof.

18. A device as claimed in claim 1 wherein said anode flow field vent valve is configured to enable said vent valve controller to monitor and control the operating state of said vent valve.

19. A device as claimed in claim 1 wherein said anode flow field vent valve is configured to enable said vent valve controller to monitor and control an amount of gas passing through said vent valve.

20. A device as claimed in claim 1 wherein said fuel cell further comprises a data store in communication with said vent valve controller.

21. A device as claimed in claim 20 wherein said data store is configured to provide respective dilution gas crossover rates for a plurality of different fuel cell component conditions.

22. A device as claimed in claim 20 wherein said data store incorporates a plurality of fuel cell condition signal data sets and is configured to provide respective dilution gas crossover rates based upon various combinations of said fuel cell condition signal data sets.

23. A device as claimed in claim 20 wherein said fuel cell condition signal data sets comprise a cathode flow field pressure data set, an anode flow field pressure data set, a fuel cell temperature data set, an anode flow field vent valve data set, and combinations thereof.

24. A device as claimed in claim 1 wherein said device comprises a plurality of fuel cells configured as a fuel cell stack.

25. A device as claimed in claim 1 wherein said device comprises a stationary generator for distributed generation of electricity and said fuel cell is configured to operate as a source of said electricity.

26. A device as claimed in claim 1 wherein said device comprises a vehicle and said fuel cell is configured to operate as a source of electrical power for said vehicle.

27. A device comprising an electrochemical fuel cell, said fuel cell comprising:

a membrane electrode assembly interposed between an anode flow field and a cathode flow field of said fuel cell;

a first reactant supply and a cathode flow field exhaust in communication with said cathode flow field;

a second reactant supply and an anode flow field vent valve in communication with said anode flow field; and

a vent valve controller programmed to control an operating state of said vent valve, wherein

a dilution gas concentration in said anode flow field is determined as a function of a calculated dilution gas crossover rate of said membrane electrode assembly, and

said vent valve is opened when said dilution gas concentration in said anode flow field is above a high threshold value and closed when said dilution gas concentration in said anode flow field is below a low threshold value.

28. A device comprising an electrochemical fuel cell, said fuel cell comprising:

a membrane electrode assembly interposed between an anode flow field and a cathode flow field of said fuel cell;

a first reactant supply and a cathode flow field exhaust in communication with said cathode flow field;

a second reactant supply and an anode flow field vent valve in communication with said anode flow field; and

a vent valve controller programmed to control an operating state of said vent valve, wherein

said vent valve is opened when a dilution gas concentration in said anode flow field is above a high threshold value and closed when said dilution gas concentration in said anode flow field is below a low threshold value, and

said dilution gas concentration is determined as a function of a signal indicative of a condition of a component of said fuel cell, a calculated dilution gas crossover rate of said membrane electrode assembly, or combinations thereof.

29. A device comprising an electrochemical fuel cell, said fuel cell comprising:

a membrane electrode assembly interposed between an anode flow field and a cathode flow field of said fuel cell;

a first reactant supply comprising oxygen and nitrogen and a cathode flow field exhaust in communication with said cathode flow field;

a second reactant supply comprising hydrogen and an anode flow field vent valve in communication with said anode flow field;

a first condition monitor configured to generate a first condition signal indicative of a partial pressure of said dilution gas within said cathode flow field;

a second condition monitor configured to generate a second condition signal indicative of a partial pressure of said dilution gas within said anode flow field; and

a vent valve controller programmed to control an operating state of said vent valve as a function of said first and second condition signals and a calculated dilution gas crossover rate of said membrane electrode assembly, wherein

said dilution gas crossover rate corresponds to a rate at which said nitrogen from said first reactant supply crosses said membrane electrode assembly

from said cathode flow field to said anode flow field and is calculated utilizing the following equation

$$V_i = 10^{-10} \frac{P_i A \Delta p_i}{t}$$

where $V_i$ represents volumetric flow across the membrane of said membrane electrode assembly, $P_i$ represents a temperature dependent permeation coefficient of said membrane, $A$ represents membrane surface area, $\Delta p_i$ represents the partial pressure differential of said dilution gas across said membrane, and $t$ represents membrane thickness, and

said vent valve controller is programmed to calculate an aggregate dilution gas concentration in said anode flow field utilizing said dilution gas crossover rate and an indication of an amount of gas vented through said anode flow field vent valve.